Spacecraft Charging and Auroral Boundary Predictions in Low Earth Orbit

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Motivation and Outline

- Auroral charging of spacecraft is an important class of space weather impacts on technological systems in low Earth orbit
- In order for space weather models to accurately specify auroral charging environments, they must provide the appropriate plasma environment characteristics responsible for charging
- Improvements in operational space weather prediction capabilities relevant to charging must be tested against charging observations

Outline

- Spacecraft charging physics
- DMSP auroral charging
- ISS solar array and auroral charging
- Characteristics of auroral charging environments
- Space environment impacts database

Acknowledgment: DMSP SSJ data provided by NOAA National Geophysics Data Center courtesy of the US Air Force

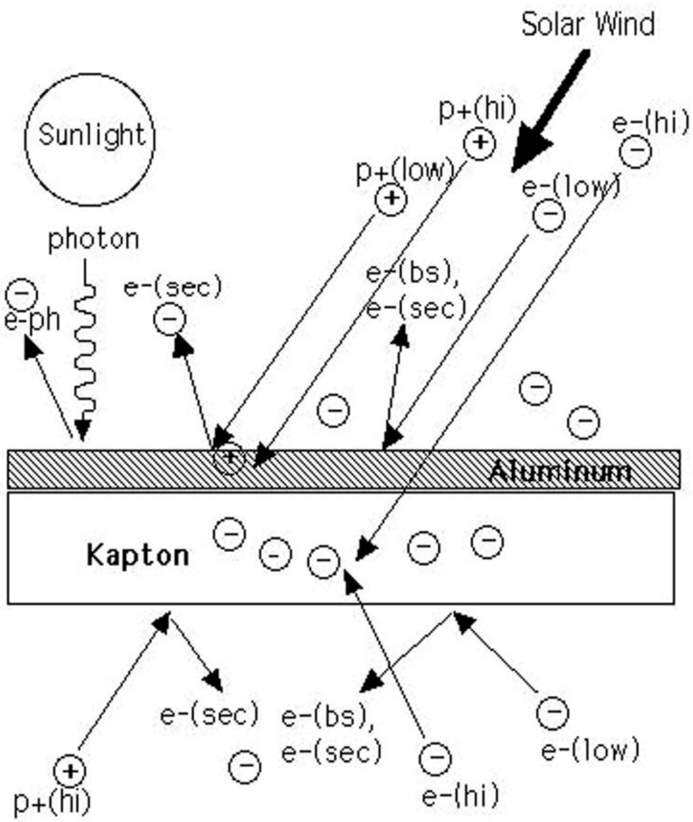
Surface Charging Physics

- Auroral charging is a process of balancing currents to and from spacecraft surfaces as a function of the spacecraft potential

$$\frac{dQ}{dt} = C\frac{dV}{dt} = \frac{d\sigma}{dt}A = \sum_k I_k$$

$$\frac{dQ}{dt} = \sum_k I_k =$$

$+I_i(V)$	**incident ions**
$-I_e(V)$	**incident electrons**
$+I_{bs,e}(V)$	**backscattered electrons**
$\pm I_c(V)$	**conduction currents**
$+I_{se}(V)$	**secondary electrons due to I_e**
$+I_{si}(V)$	**secondary electrons due to I_i**
$+I_{ph,e}(V)$	**photoelectrons**



(Garrett and Minow, 2004)

DMSP Charging


US Air Force

DMSP Auroral Charging

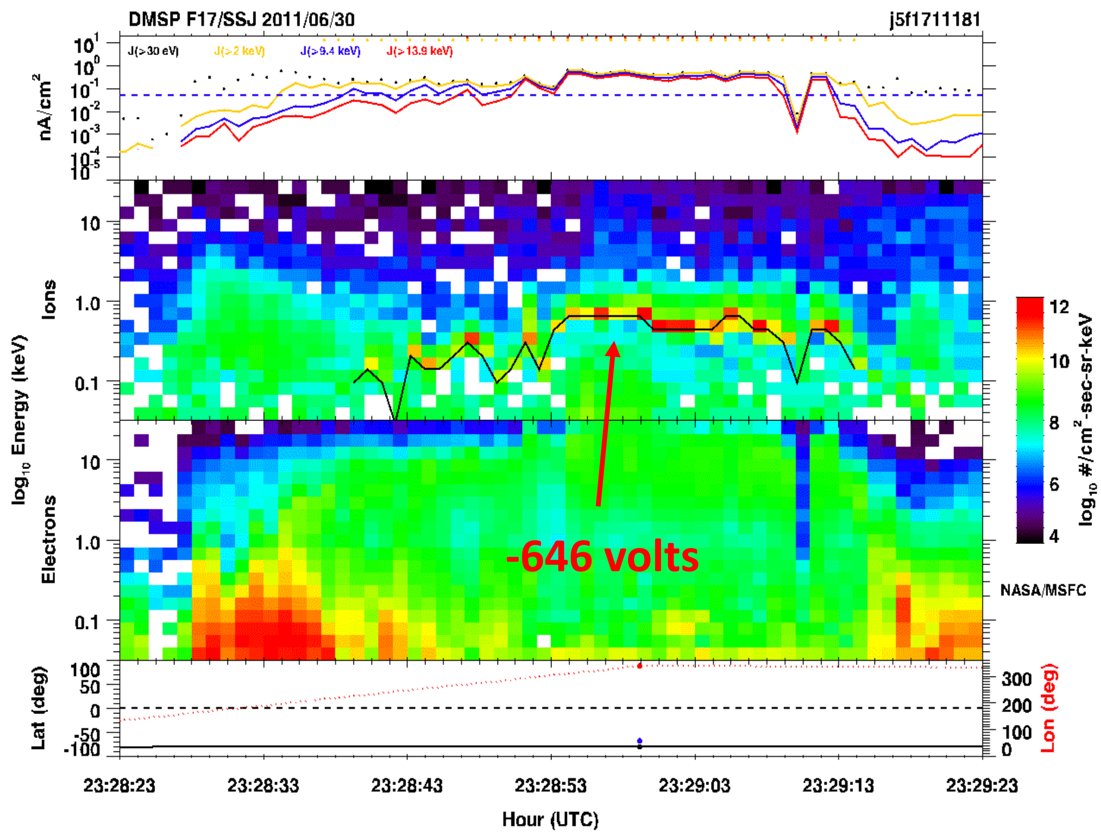
- Low energy (E_0 ~ 0) background ions accelerated by the spacecraft potential show up as sharp "line" of high ion flux in single channel

$$E = E_0 + q\Phi$$

- Assume initial energy E_0 = 0 with singly charge ions (O^+, H^+) and read potential (volts) directly from ion line energy (eV)

- DMSP SSJ4, SSJ5 detectors
  - Electrons: 20 channels
    30 eV to 30 keV
  - Ions: 20 channels
    30 eV to 30 keV
  - Nominal channel energies used for this work

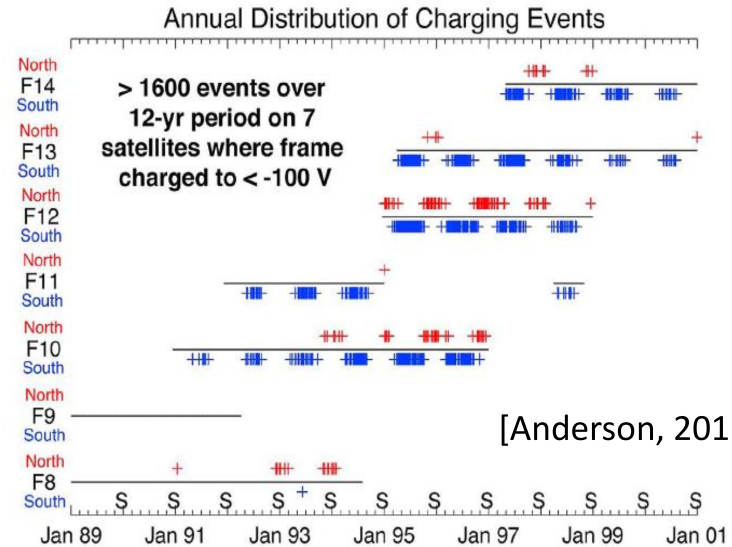
"Ion Line" Charging Signature



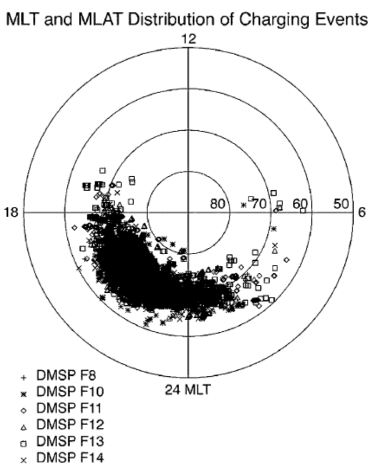
Auroral Charging Conditions

Necessary conditions for high-level (≥100 V) auroral charging*

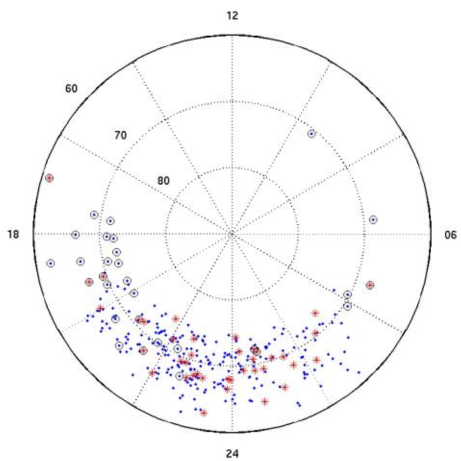
- No sunlight (or ionosphere below spacecraft in darkness)
- Intense electron flux $>10^8$ e/cm^2-s-sr at energies of 10’s keV
- Low ambient plasma density ($<10^4$ #/cm^3)



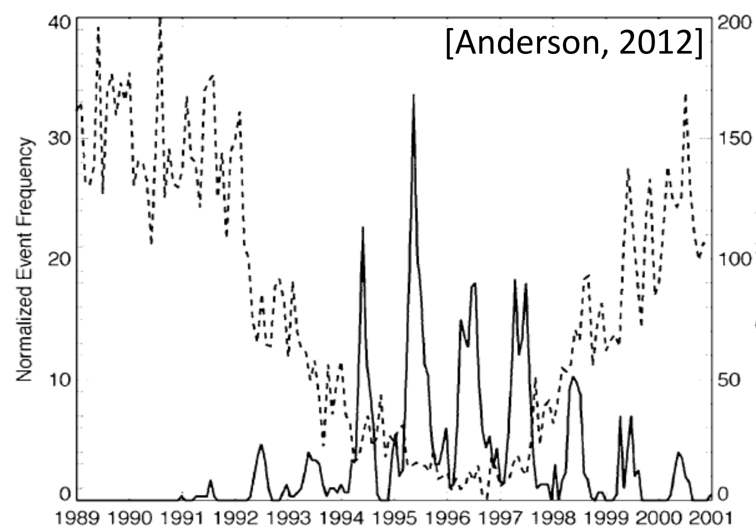
[Anderson, 2012]



[Anderson, 2012]



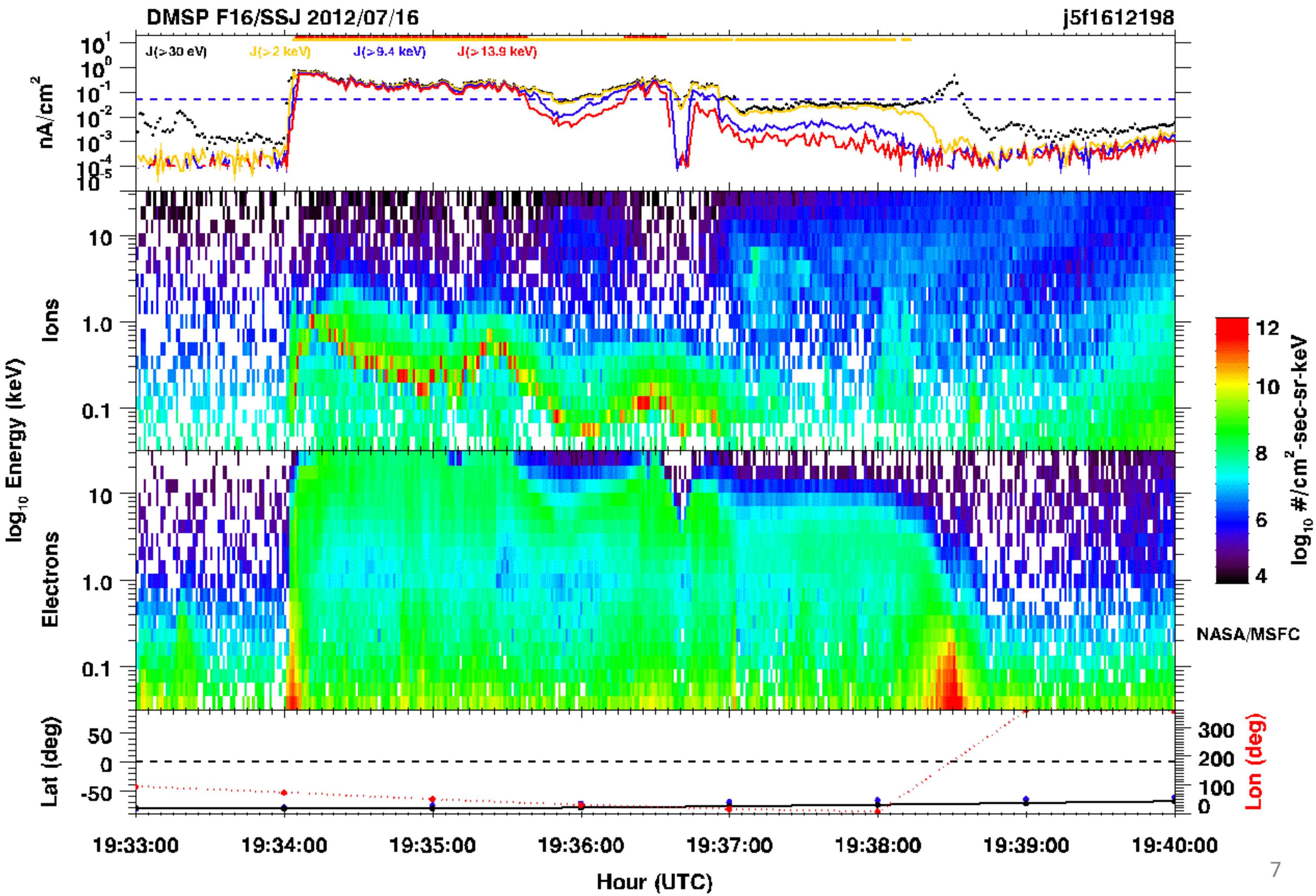
[Eriksson and Wahlund, 2006]



[Anderson, 2012]

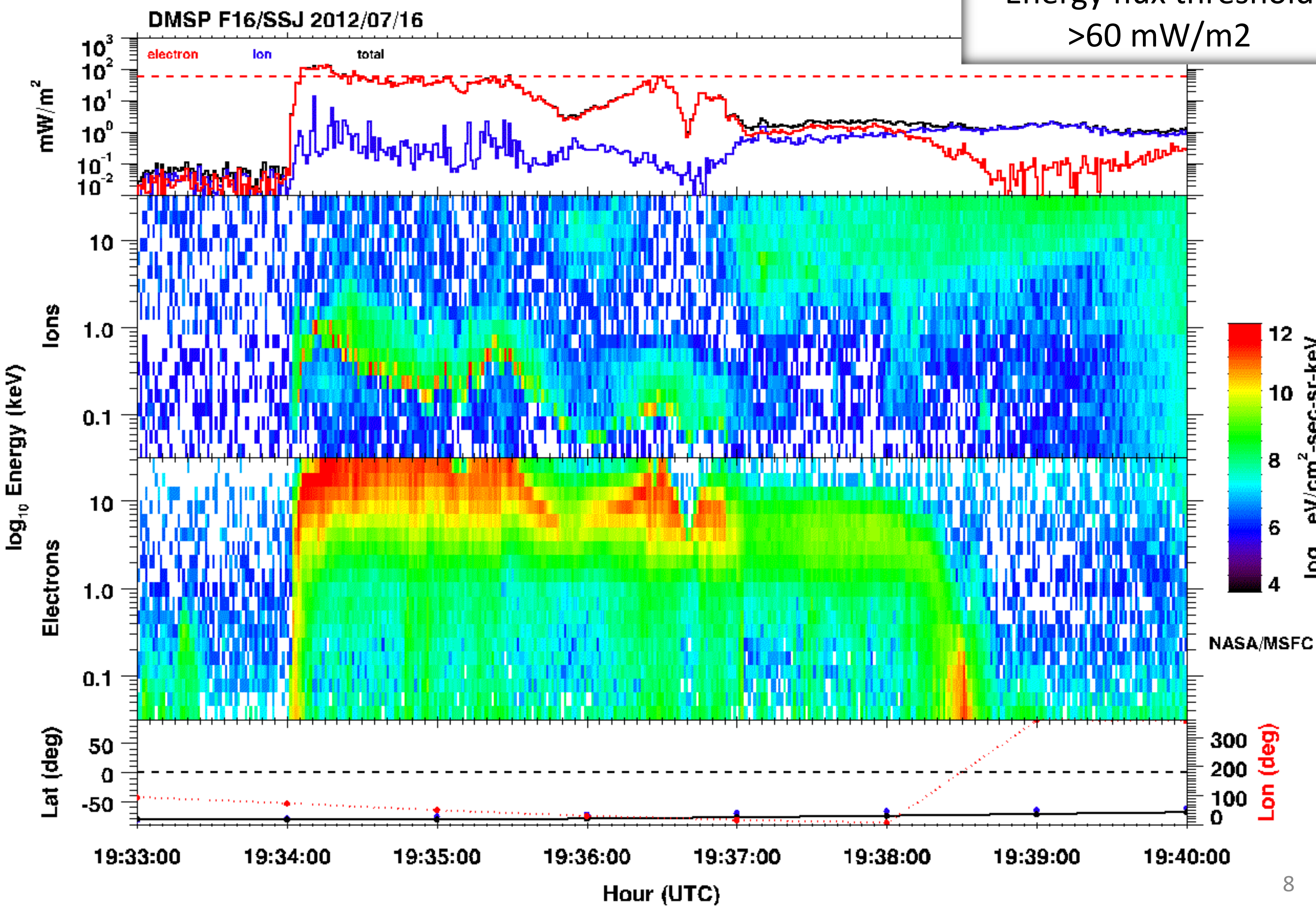
*Gussenhoven et al., 1985; Frooninckx and Sojka, 1992; Eriksson and Wahlund, 2006.

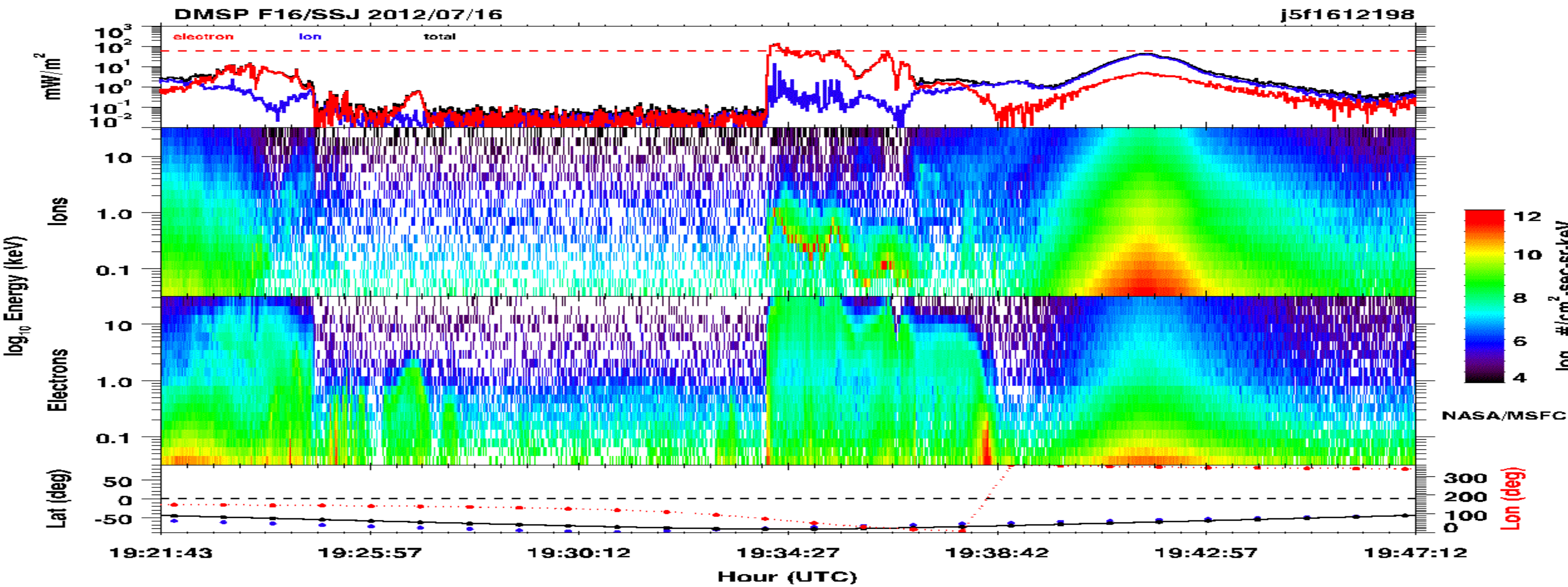
DMSP F16: -1000 V Charging Event

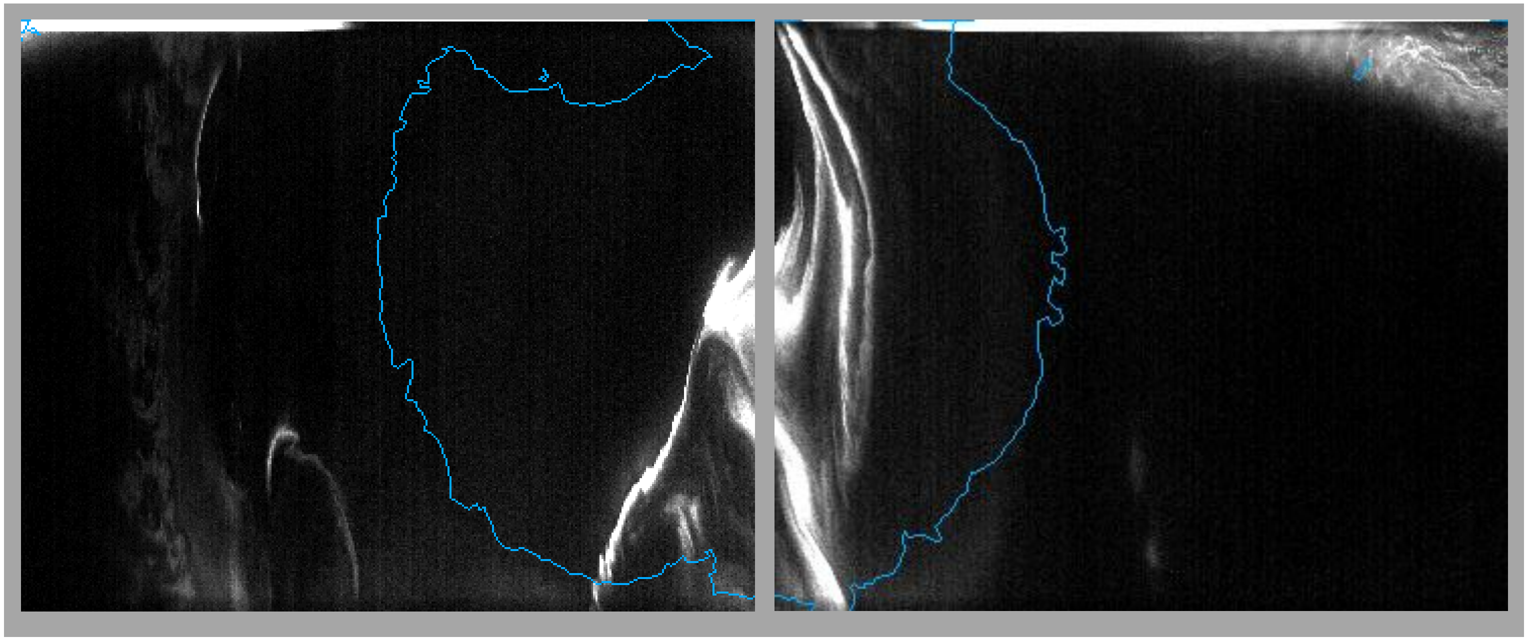


Energy Flux

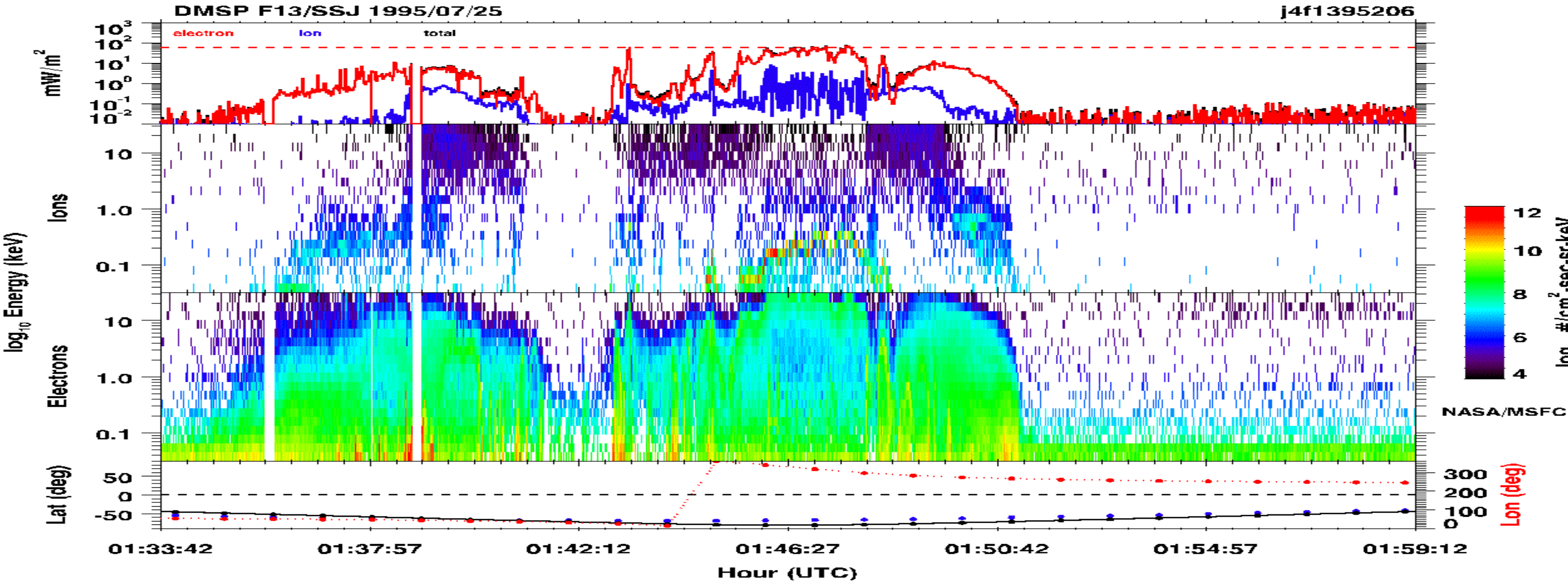
Energy flux threshold
>60 mW/m2

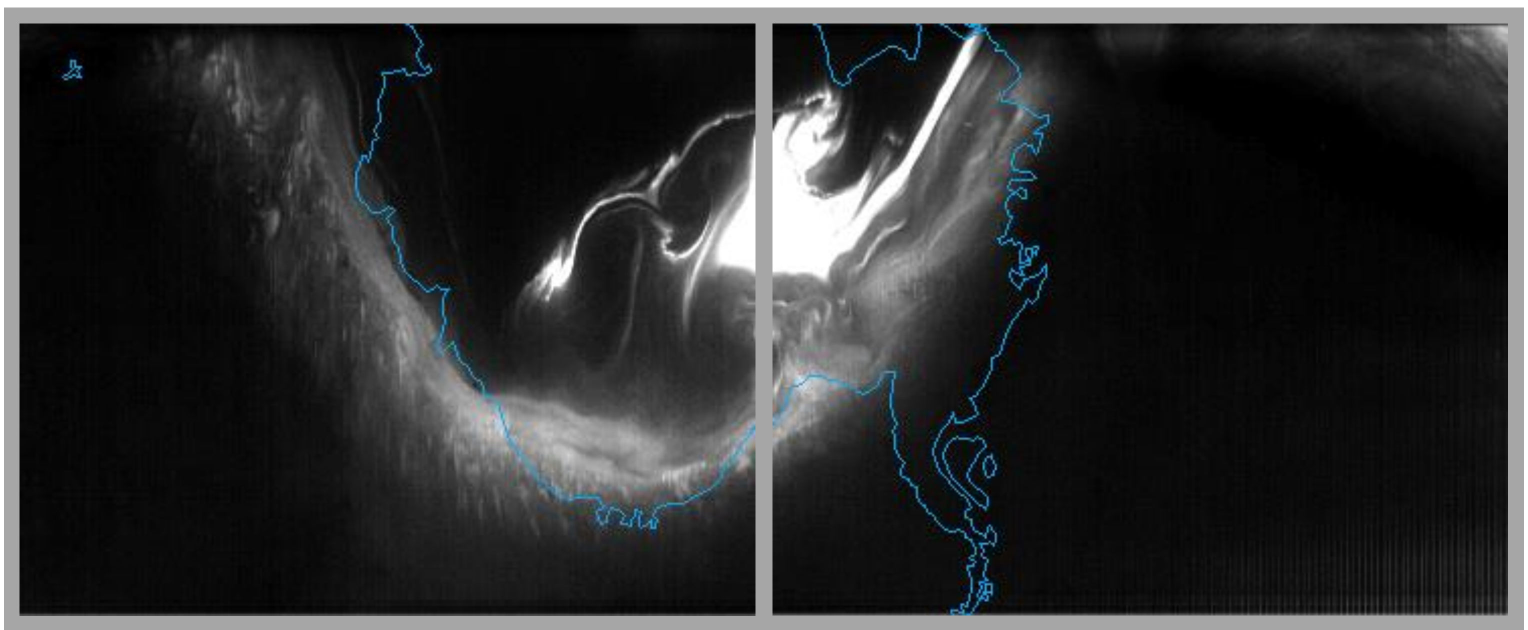






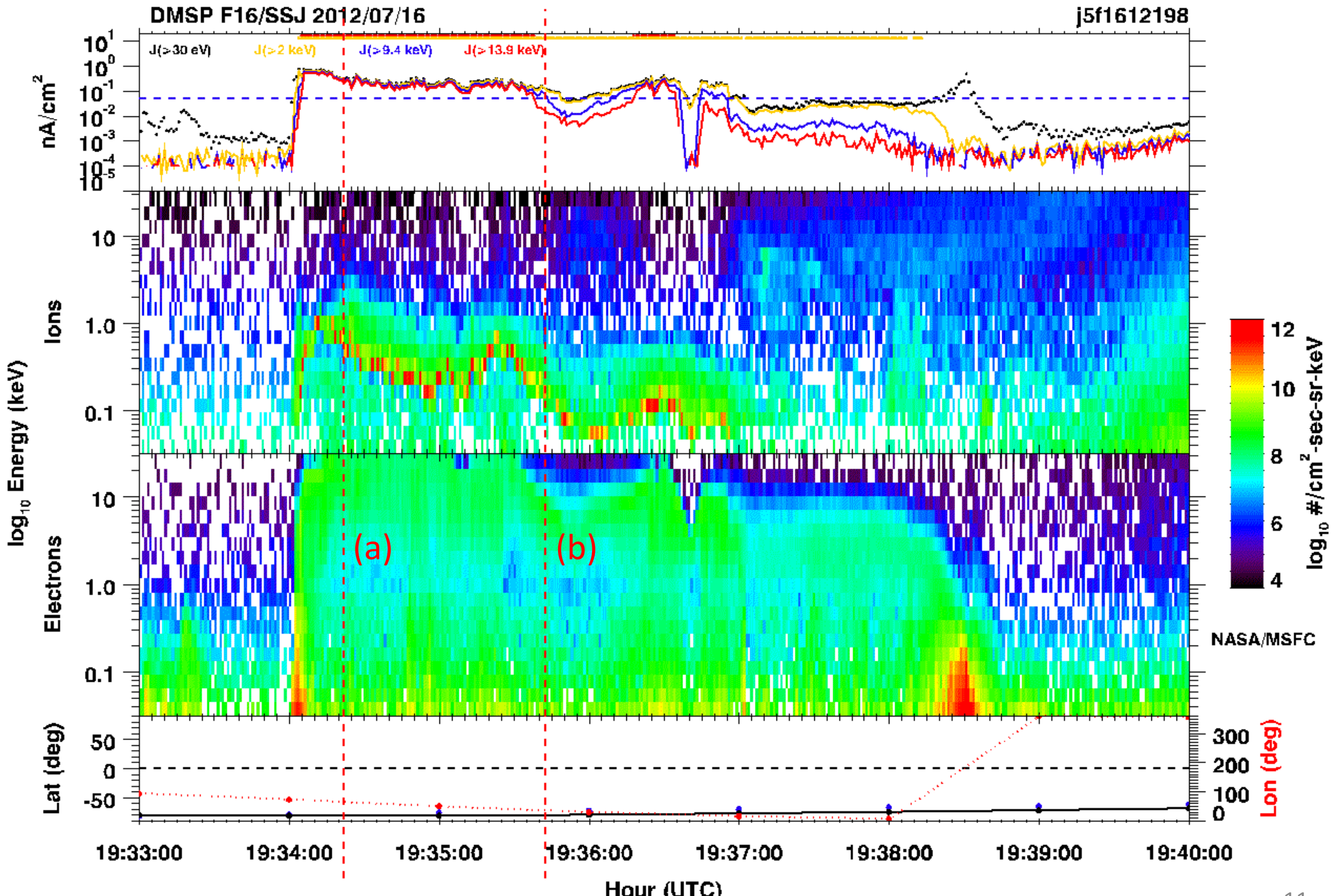
2012-07-16 19:21:43.0 2012-07-16 19:34:27.0 2012-07-16 19:47:12.0



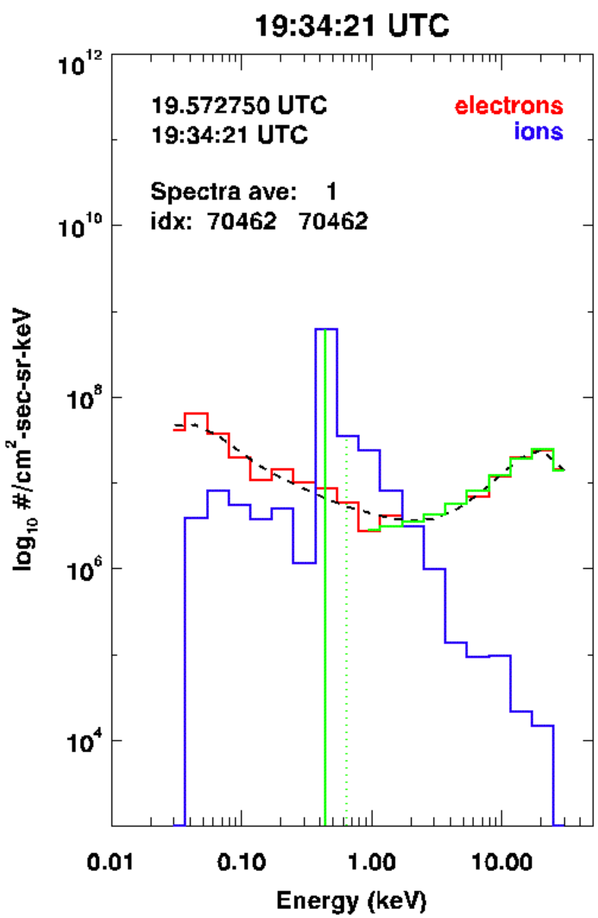


1995-07-25 01:33:42.0 **1995-07-25 01:46:27.0** **1995-07-25 01:59:12.0**

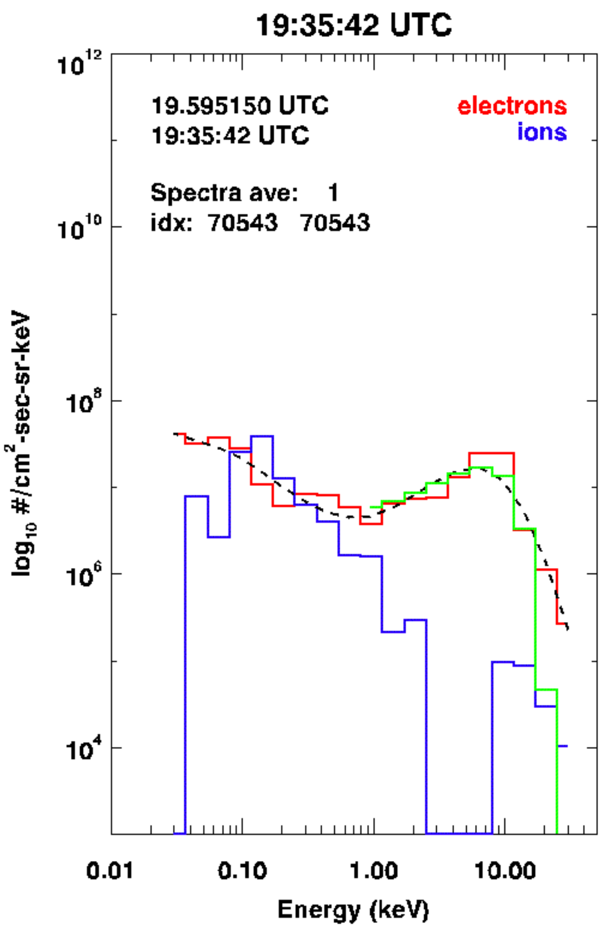
Individual Spectra



Individual Spectra



(a)



(b)

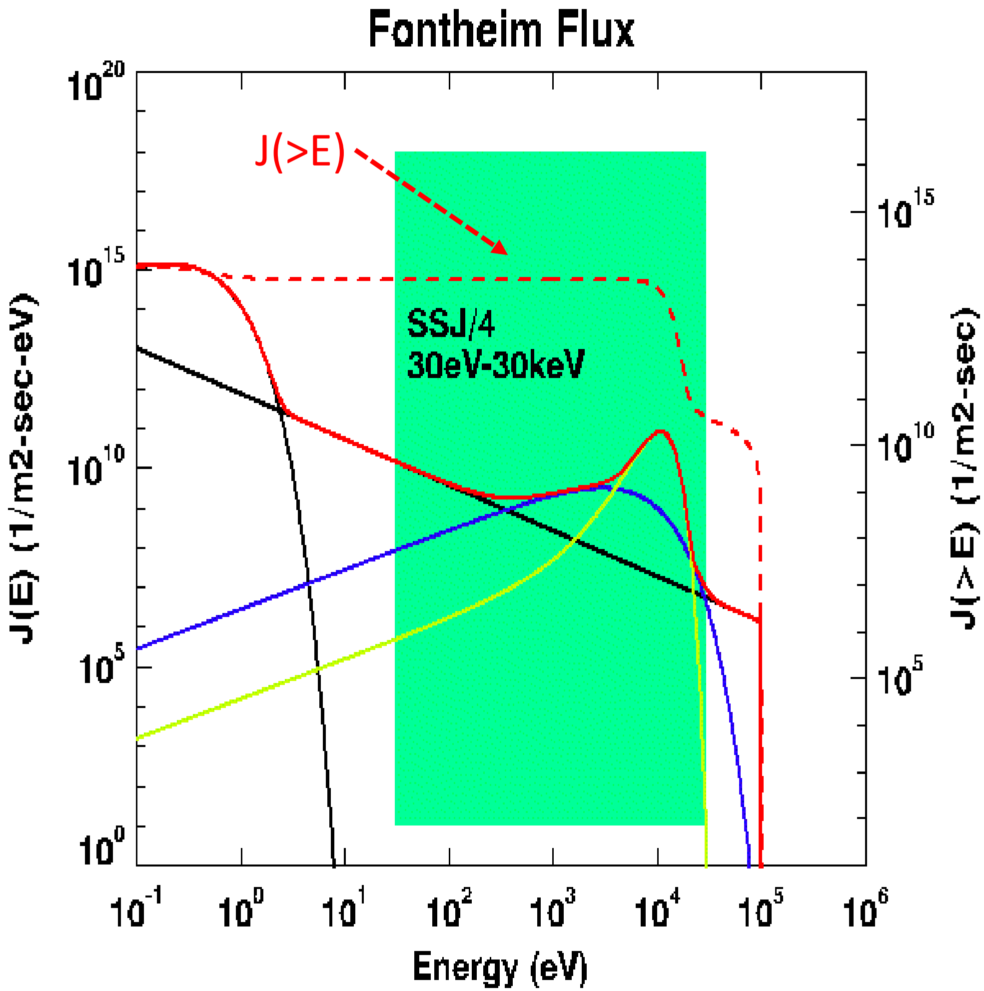
Fontheim Distribution

Ambient background
n=1.0e10 1/m3
Te=0.2 eV

Maxwellian
Jmax = 4.0e-6 A/m²
Te = 3.0e3 eV

Gaussian (beam)
Jgau =0.9e-4 A/m²
Egau = 10.0e3 eV beam energy
dgau = 4.0e3 eV beam width

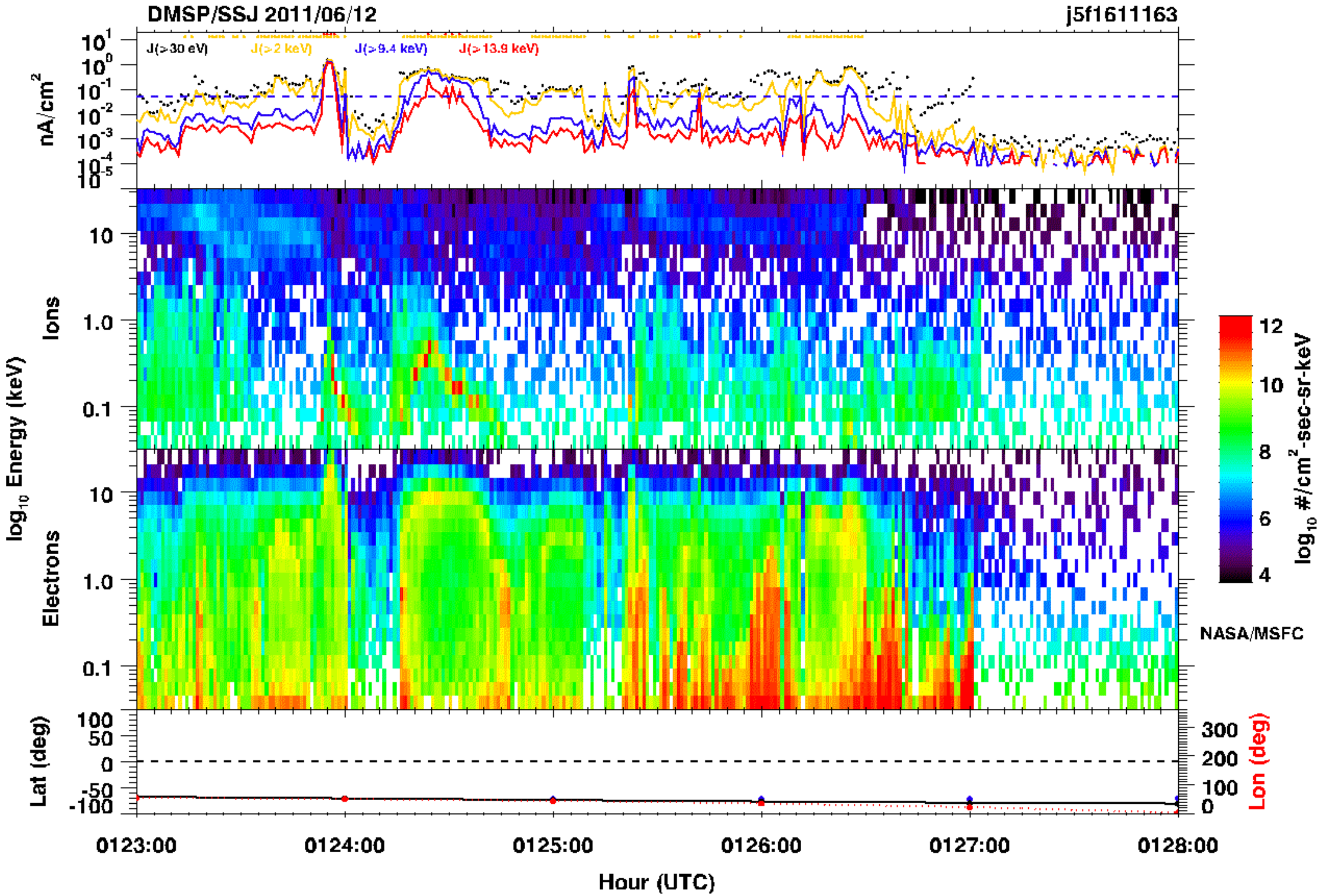
Power Law
Jpwr = 3.0e-7 A/m²
alpha = 1.15 exponent
E1=50.0 eV, first energy
E2=1.0e5 eV, second energy



$$\mathrm{Flux}(E) = \sqrt{\frac{e}{2\pi\theta m_e}}\frac{E}{\theta} n \exp\left(-\frac{E}{\theta}\right) + \pi\zeta_{max} E \exp\left(-\frac{E}{\theta_{max}}\right) + \pi\zeta_{gauss} E \exp\left(-\left(\frac{E_{gauss}-E}{\Delta}\right)^2\right) + \pi\zeta_{power} E^{-\alpha}$$

[Davis et al., 2011]

Inverted V, Broadband Aurora

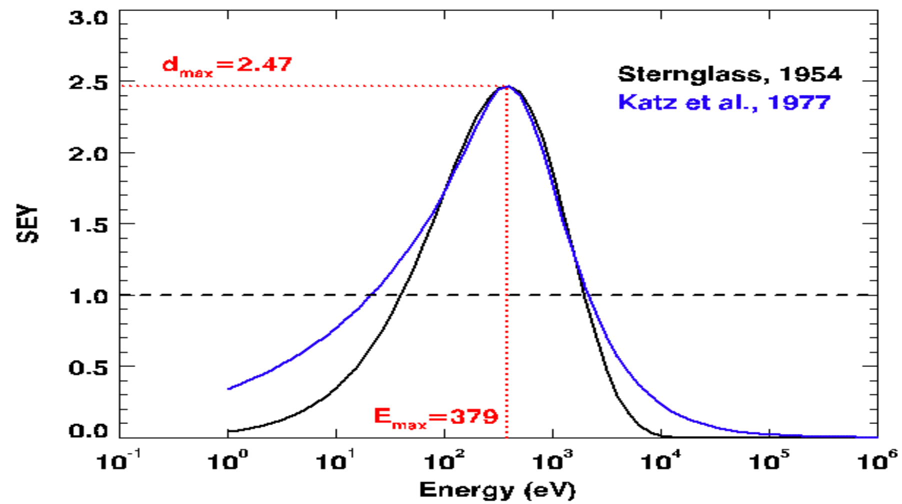


Secondary Electron Yields

Charging is suppressed when SEY > 1

$$\frac{dQ}{dt} = \sum_k I_k = +I_i - I_e + I_{se} + I_{ph,e}$$

$$= +I_i - I_e(1-\delta) + I_{ph,e}$$

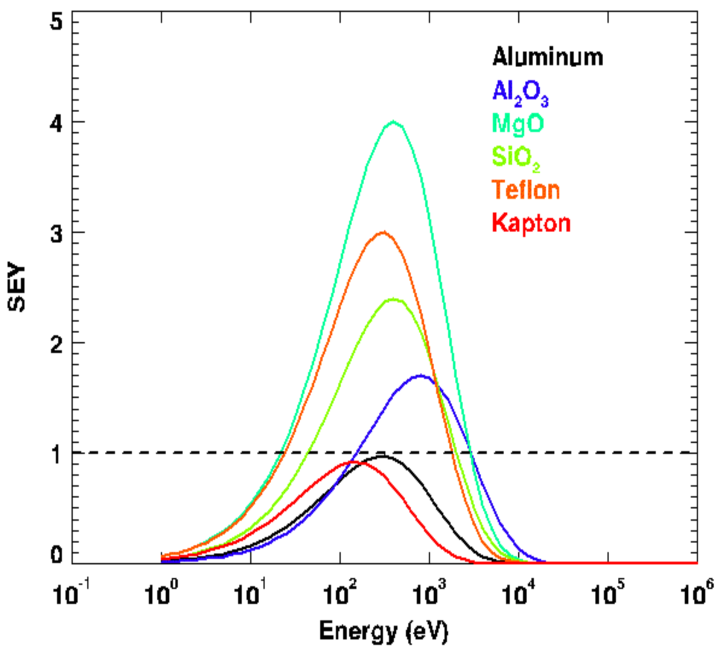


Sternglass, 1954

$$\delta_e(E,\theta) = \delta_{e,\max} \frac{E}{E_{\max}} \exp(2 - 2\sqrt{E/E_{\max}}) \exp[2(1-\cos\theta)]$$

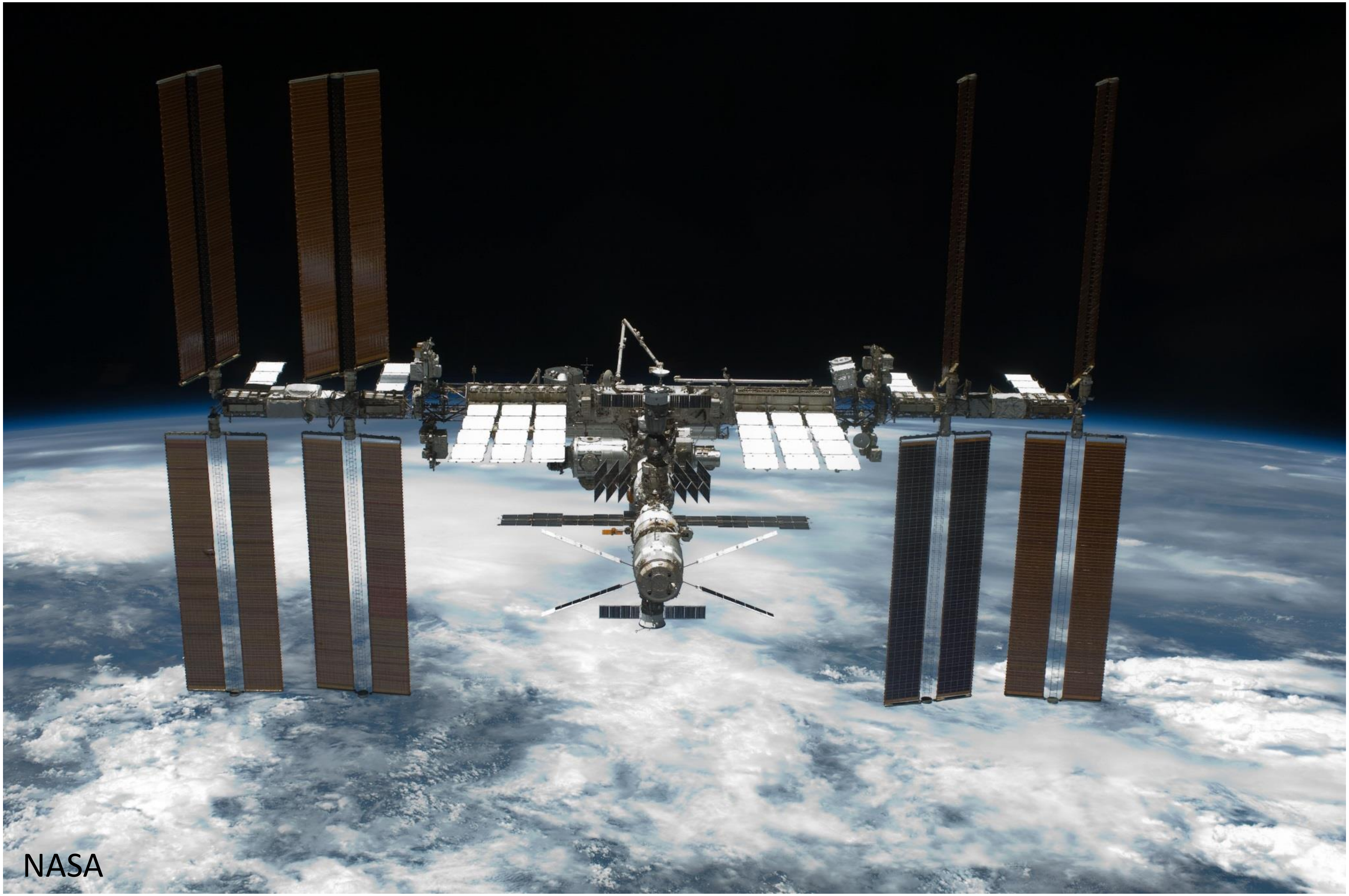
Katz et al., 1977; Whipple, 1981

$$\delta_e(E,\theta) = \frac{1.114\delta_{e,\max}}{\cos\theta}\left[\frac{E}{E_{\max}}\right]^{0.35}\left\{1-\exp\left[-2.28\cos\theta\left[\frac{E_{\max}}{E}\right]^{1.35}\right]\right\}$$



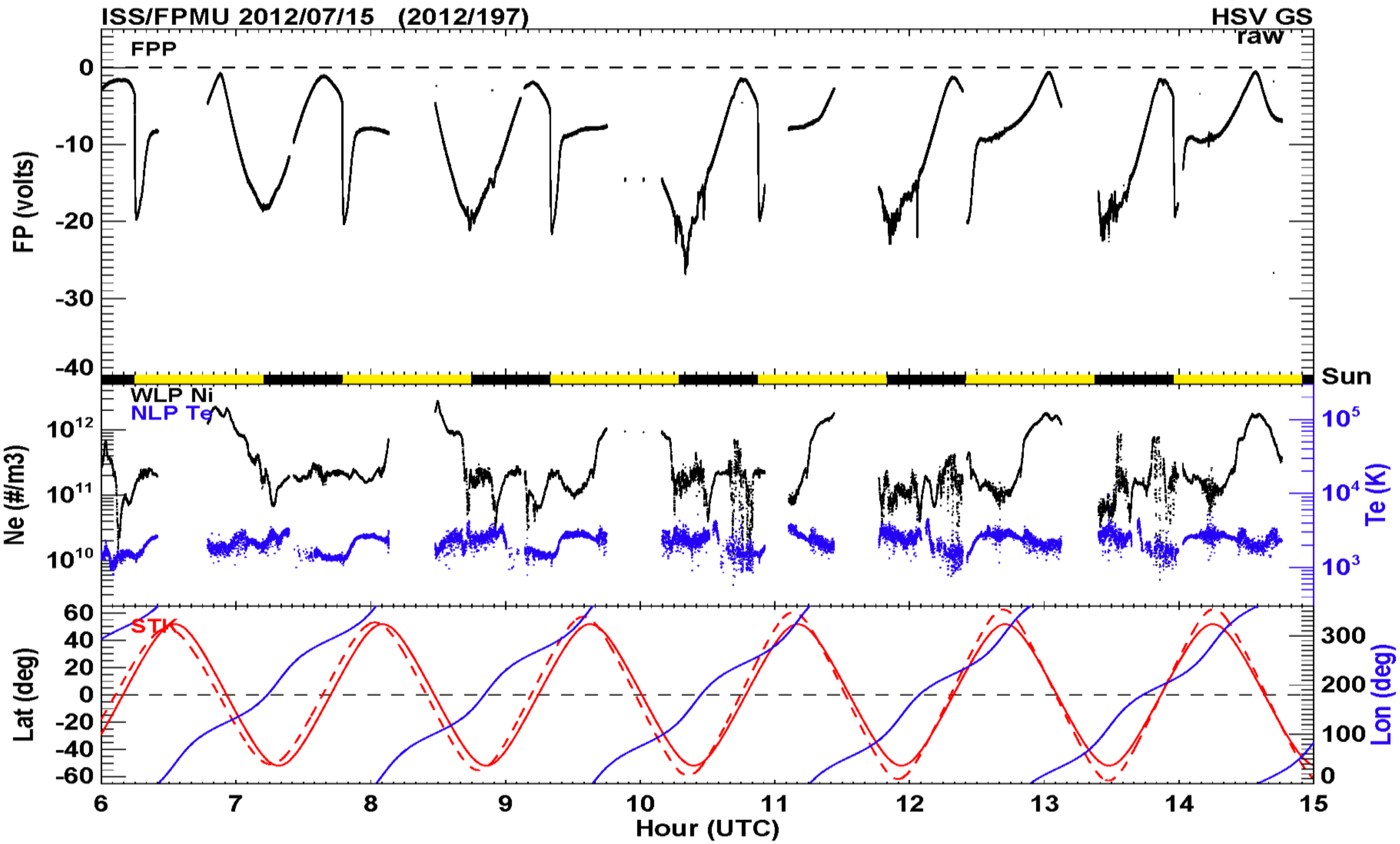
δ_m, E_m from Hasting and Garrett, 1996

ISS Charging



International Space Station: 15 July 2012

Potential variations due to (a) vxB.L (b) eclipse exit solar array (c) auroral charging



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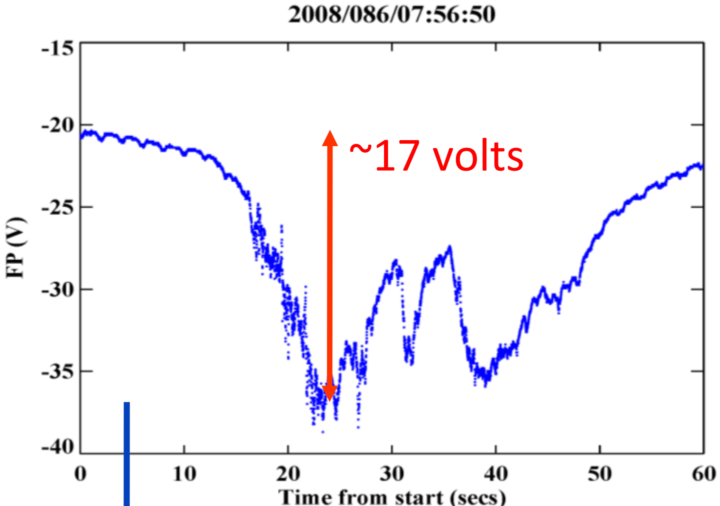
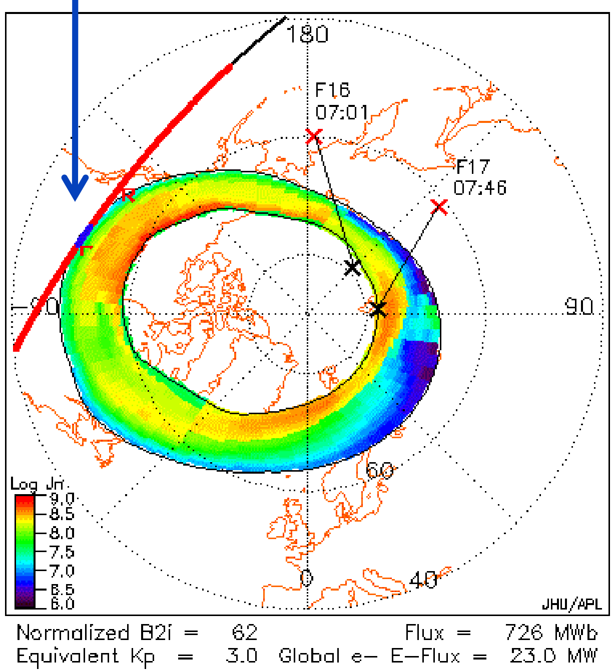
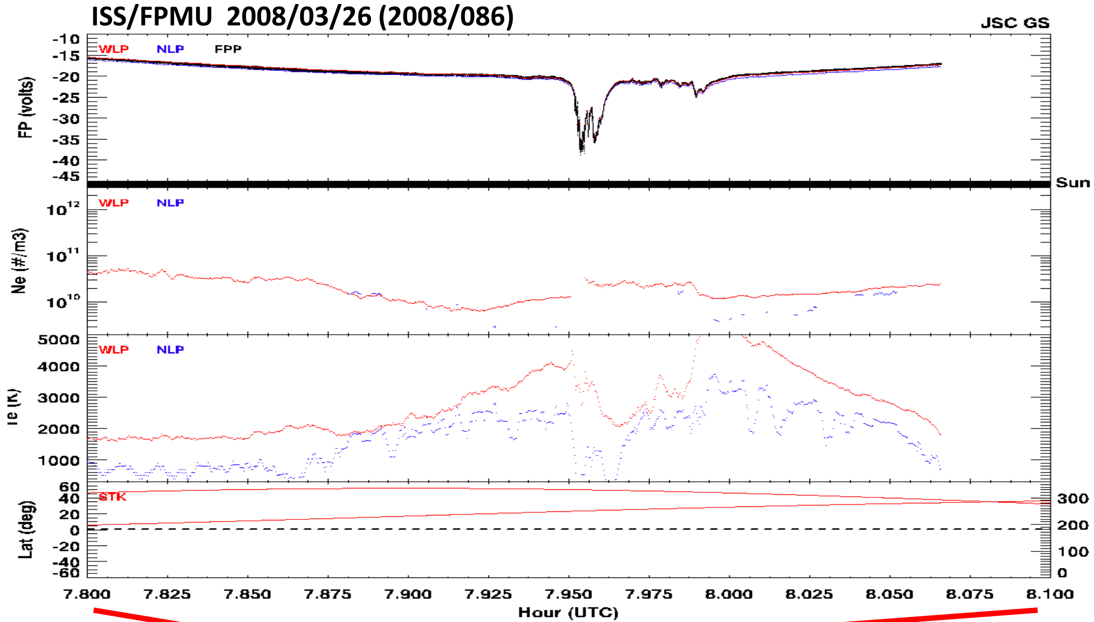
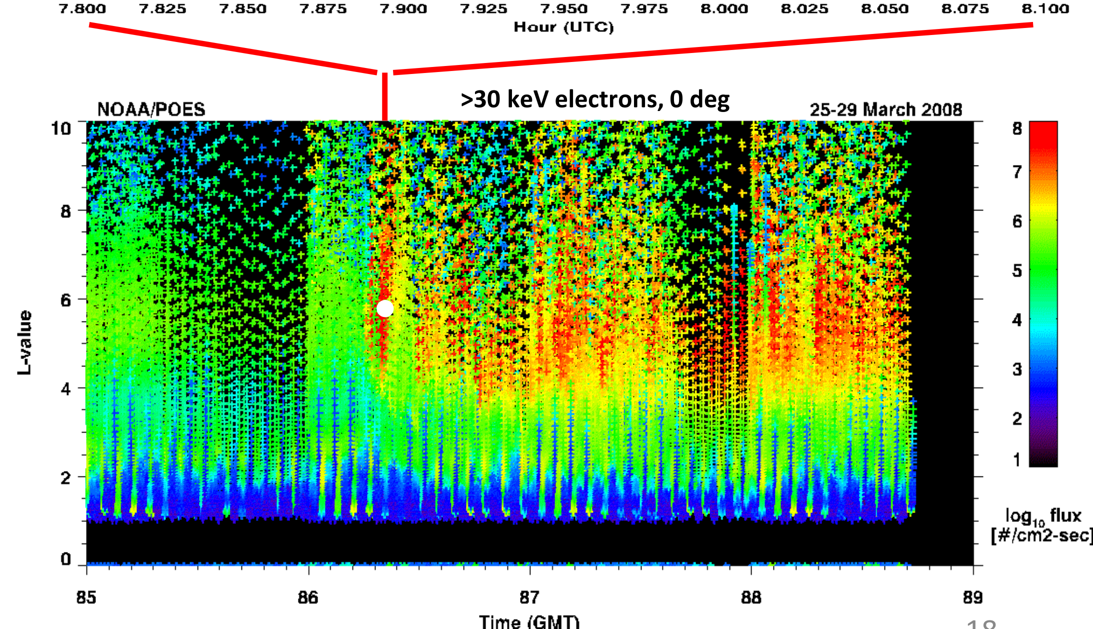
26 March 2008 -- Auroral Charging



26 Mar 2008 07:30 – 08:00 UT

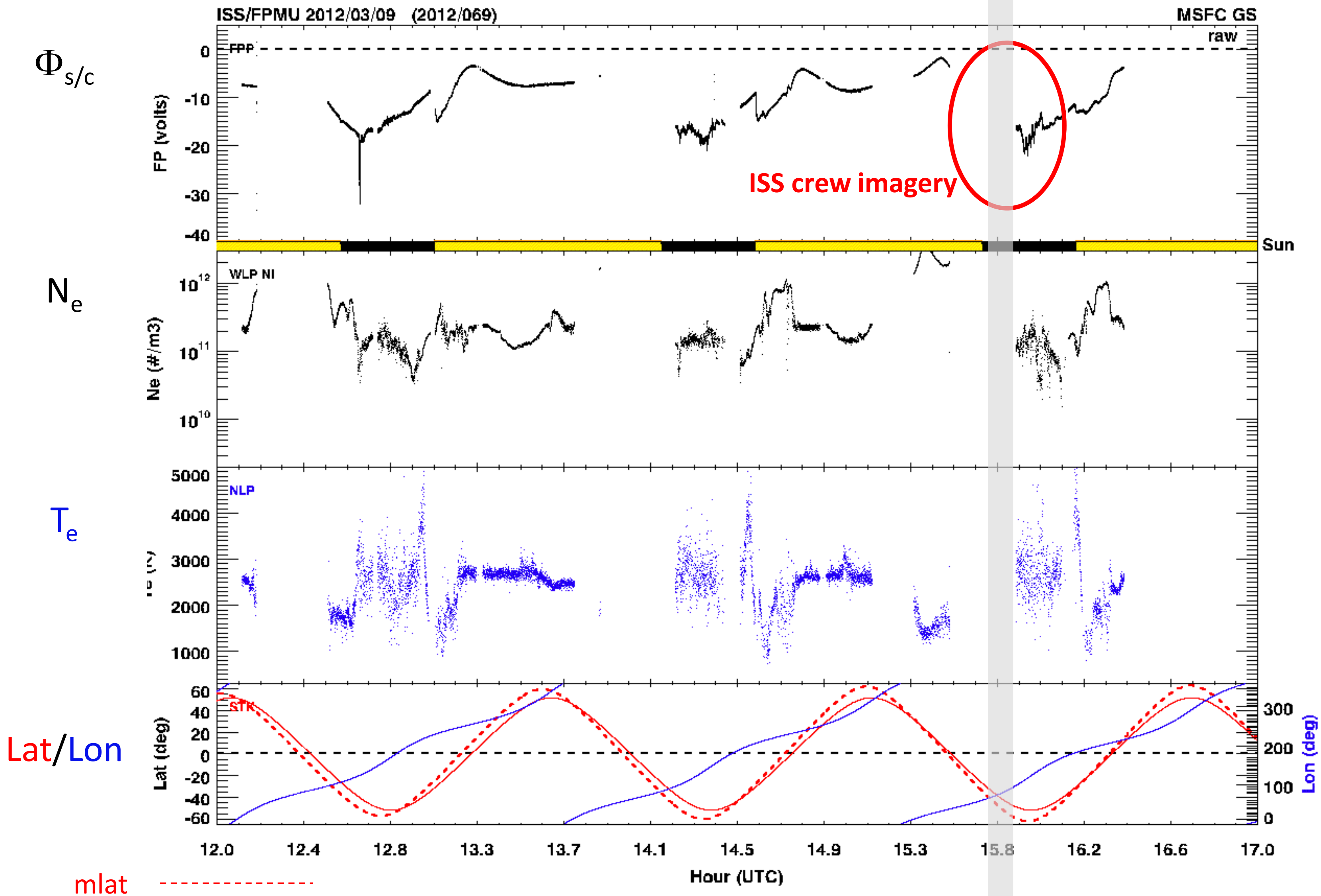






[adapted from *Craven et al.*, 2009]

9 March 2012

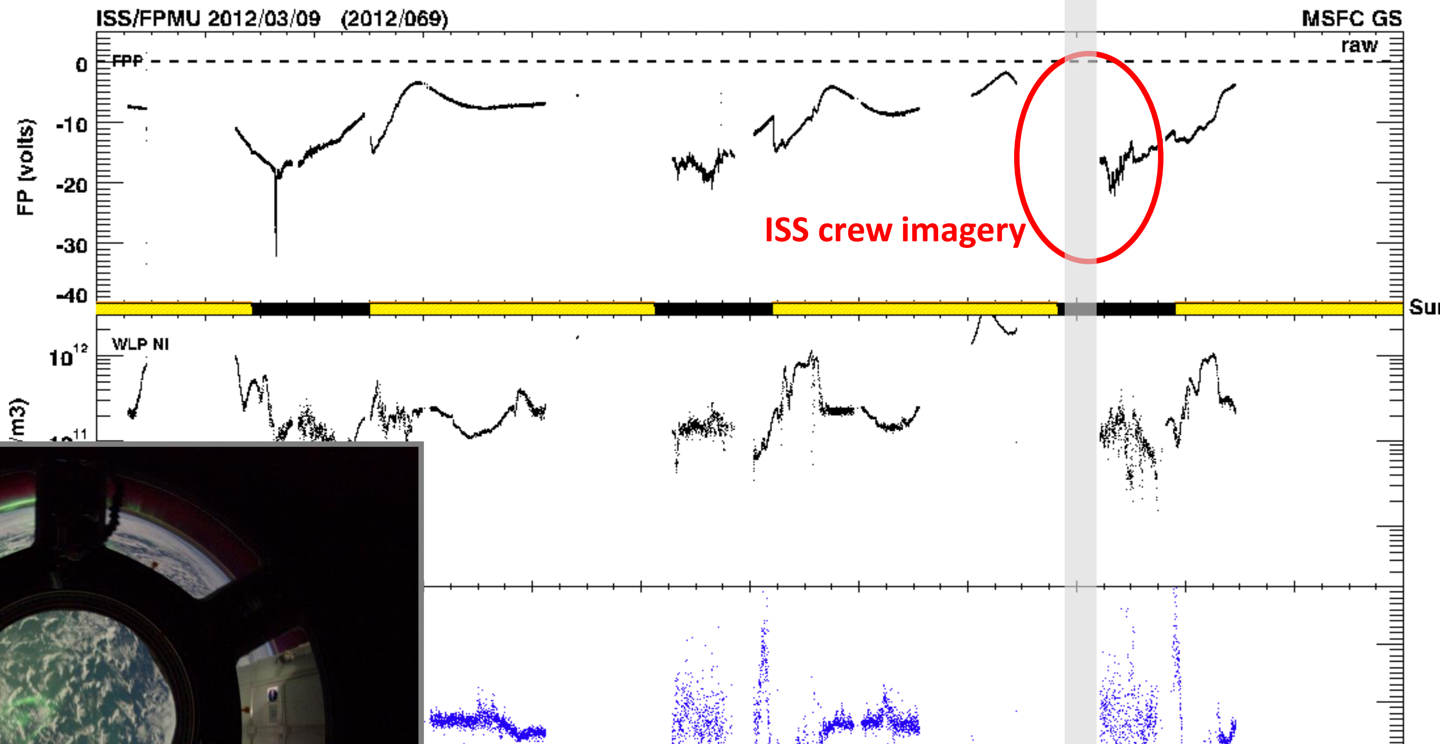


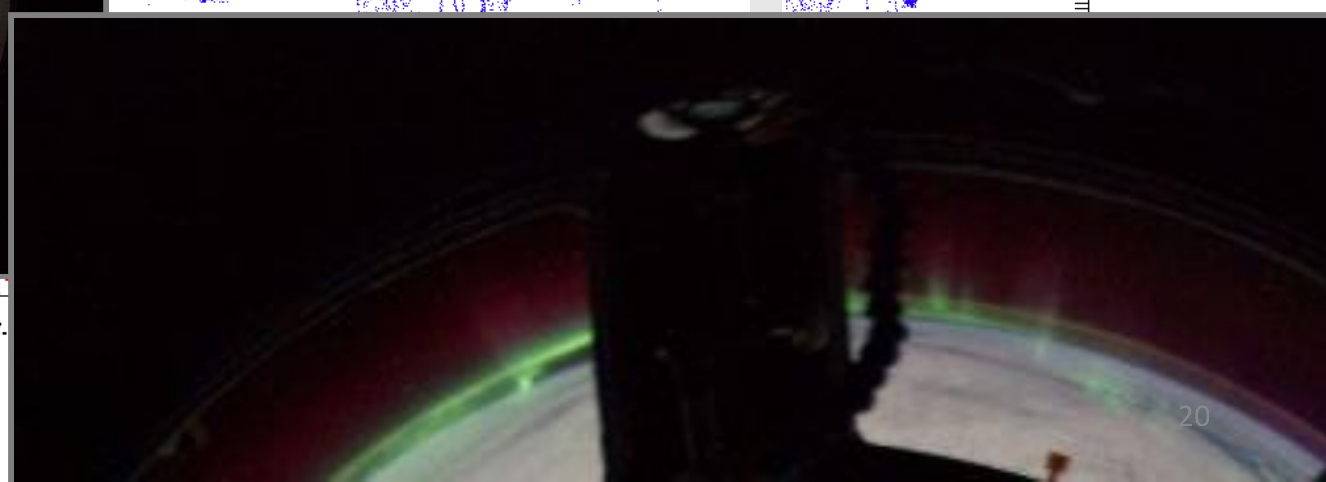
ISS/FPMU 2012/03/09 (2012/069)
MSFC GS
raw
FPP
FP (volts)
ISS crew imagery
Sun
WLP NI
Ne (#/m3)
NLP
STK
Lat (deg)
Lon (deg)
Hour (UTC)
$\Phi_{s/c}$
N_e
T_e
Lat/Lon
mlat

9 March 2012

$\Phi_{s/c}$

N_e





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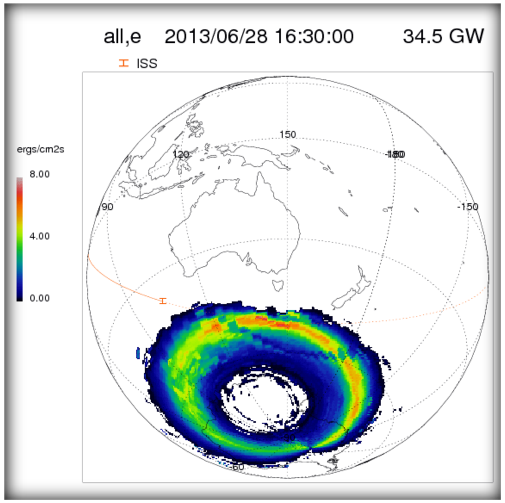
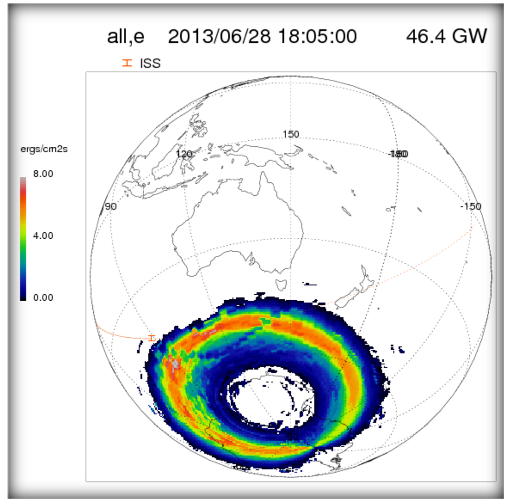
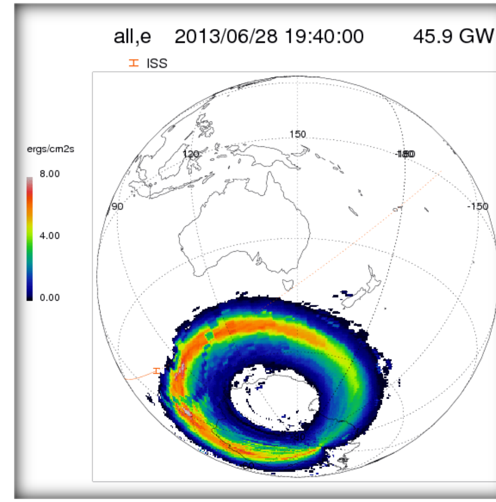
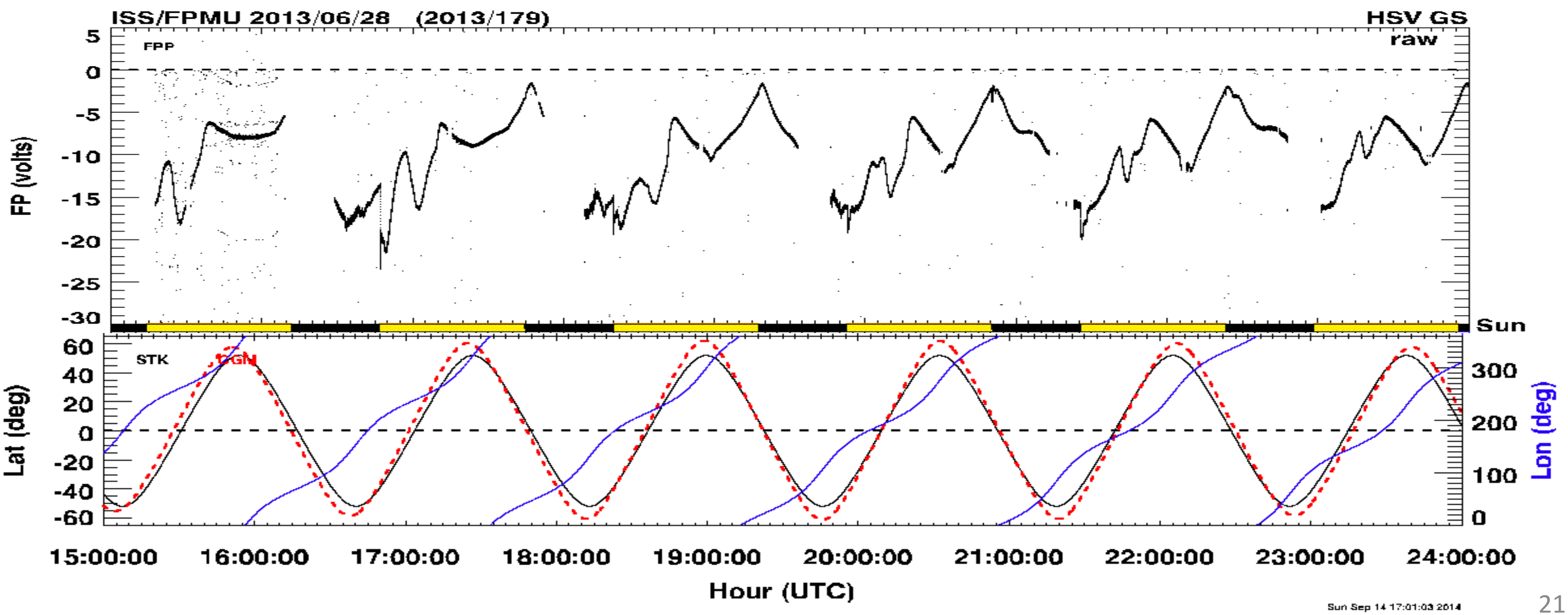
iSWA Ovation Prime, ISS Charging



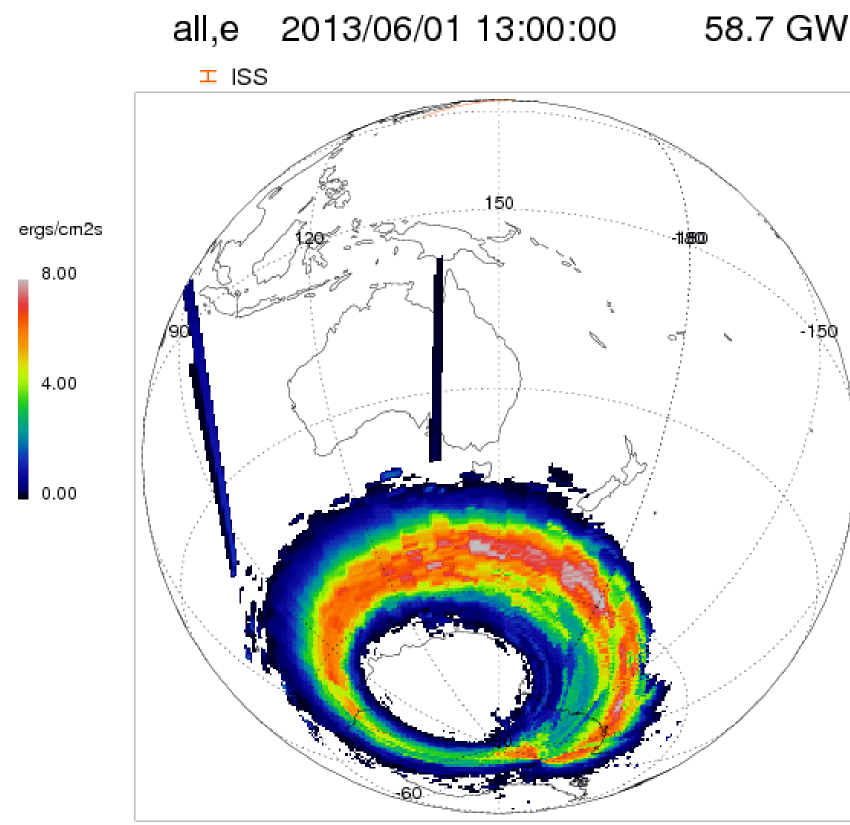




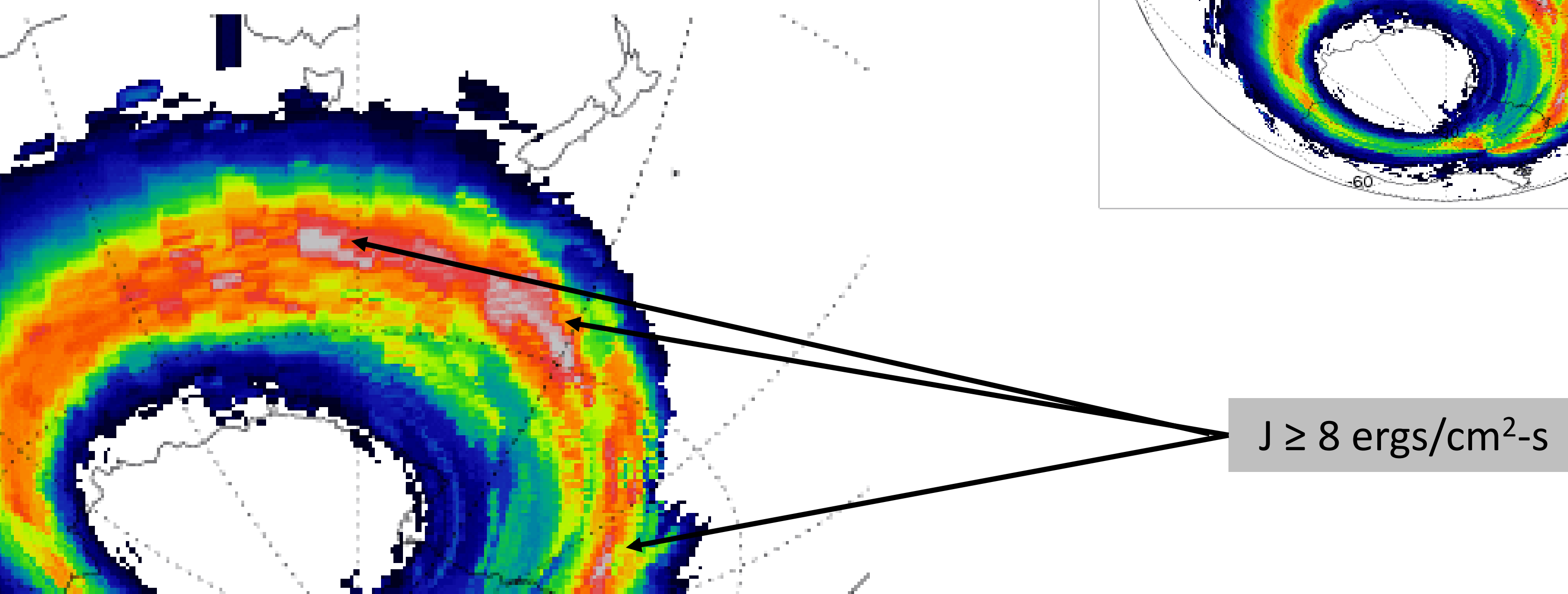


Aurora Models

- NASA CCMC implementation of Ovation Prime is a good example of an auroral model providing total energy flux
- Total ions, electrons, and ions+electrons energy flux to 8 erg/cm^2-s (=mW/m^2)

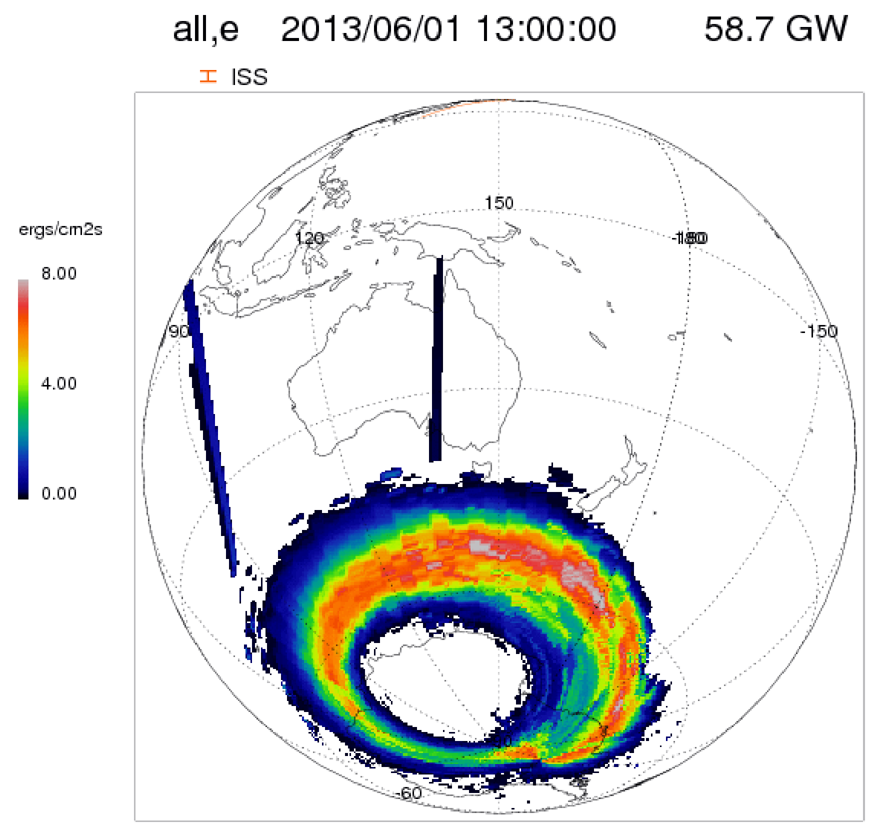


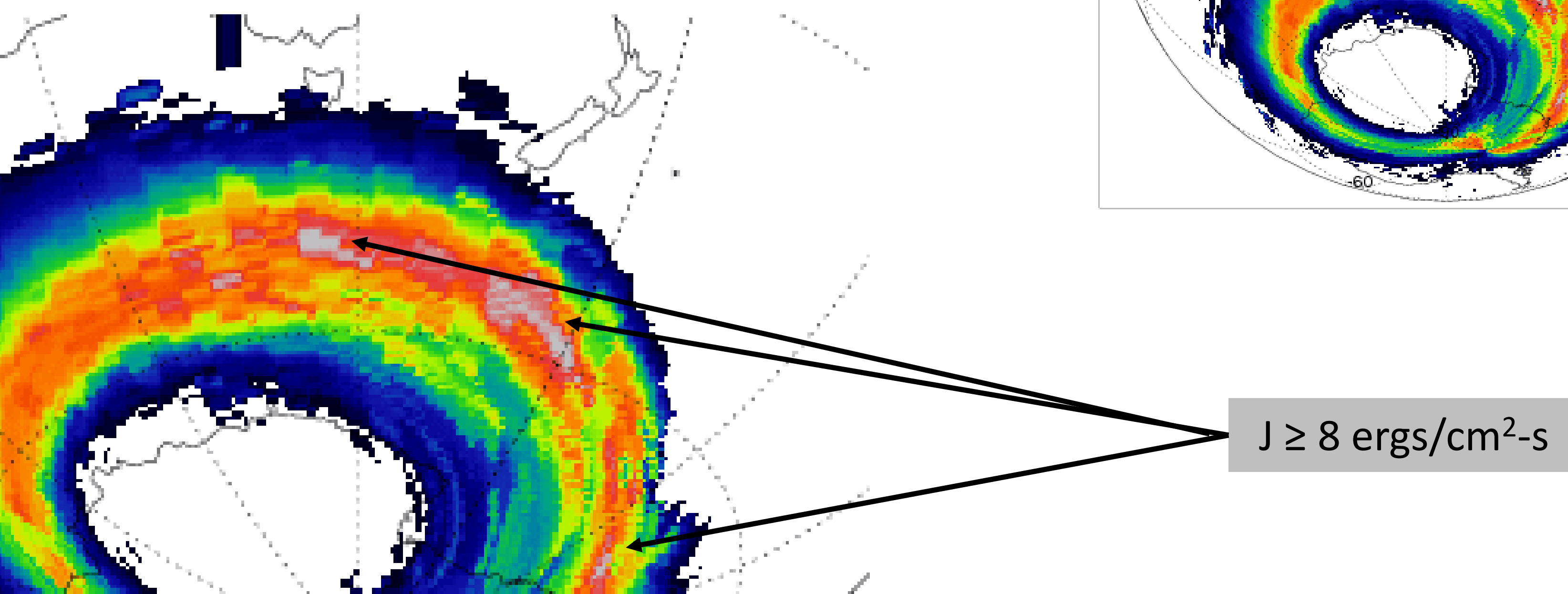
NASA CCMC



Aurora Models

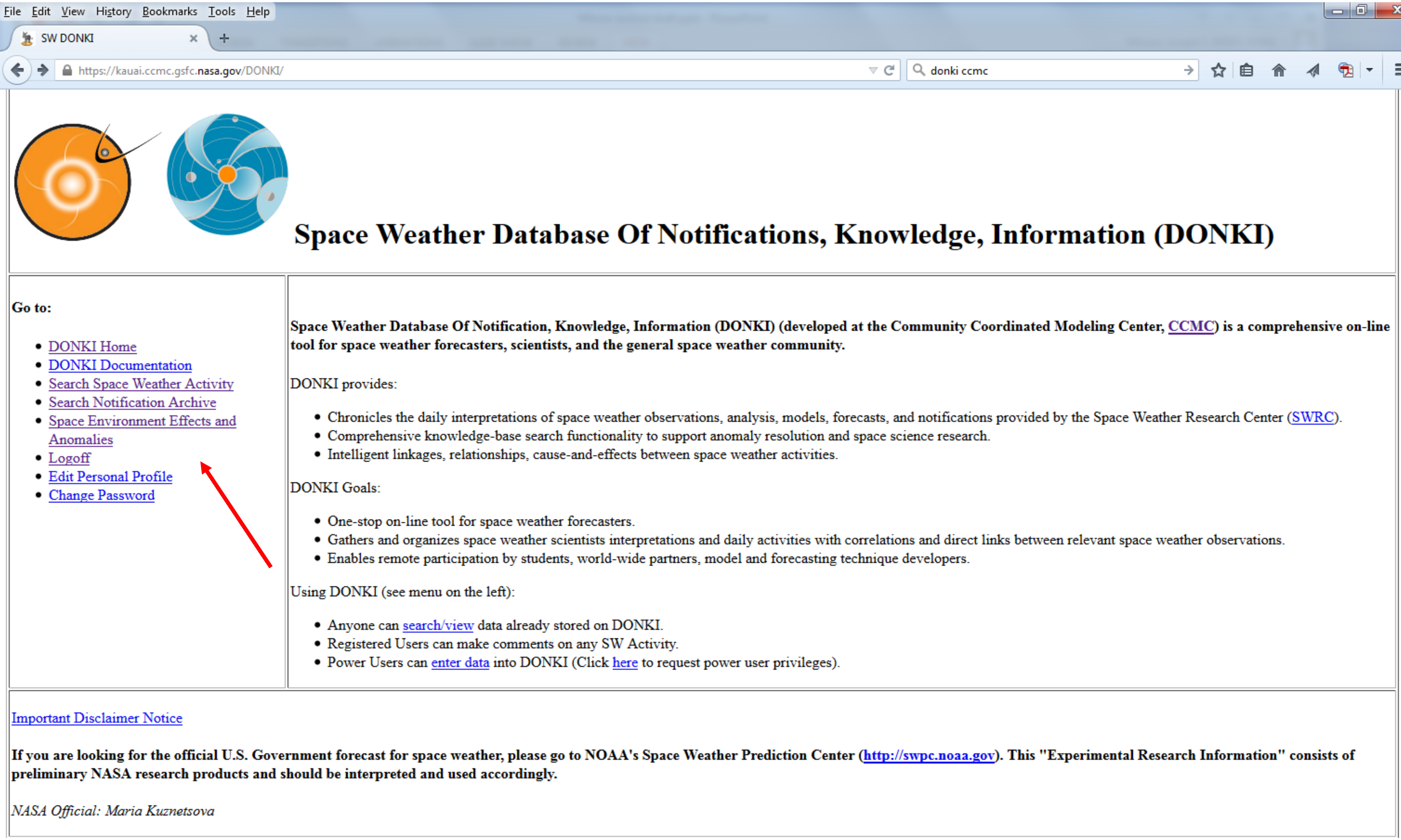
- NASA CCMC implementation of Ovation Prime is a good example of an auroral model providing total energy flux
- Total ions, electrons, and ions+electrons energy flux to 8 erg/cm^2-s (=mW/m^2)
- Increase the energy flux coverage to include 10’s to 100’s ergs/cm2-s to consider auroral charging regime
- Energy flux for J_E(≥10 keV) erg/cm^2-s





NASA CCMC

CCMC DONKI



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Space Weather Database Of Notifications, Knowledge, Information (DONKI)

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Space Weather Database Of Notification, Knowledge, Information (DONKI) (developed at the Community Coordinated Modeling Center, CCMC) is a comprehensive on-line tool for space weather forecasters, scientists, and the general space weather community.

DONKI provides:

- Chronicles the daily interpretations of space weather observations, analysis, models, forecasts, and notifications provided by the Space Weather Research Center (SWRC).
- Comprehensive knowledge-base search functionality to support anomaly resolution and space science research.
- Intelligent linkages, relationships, cause-and-effects between space weather activities.

DONKI Goals:

- One-stop on-line tool for space weather forecasters.
- Gathers and organizes space weather scientists interpretations and daily activities with correlations and direct links between relevant space weather observations.
- Enables remote participation by students, world-wide partners, model and forecasting technique developers.

Using DONKI (see menu on the left):

- Anyone can search/view data already stored on DONKI.
- Registered Users can make comments on any SW Activity.
- Power Users can enter data into DONKI (Click here to request power user privileges).

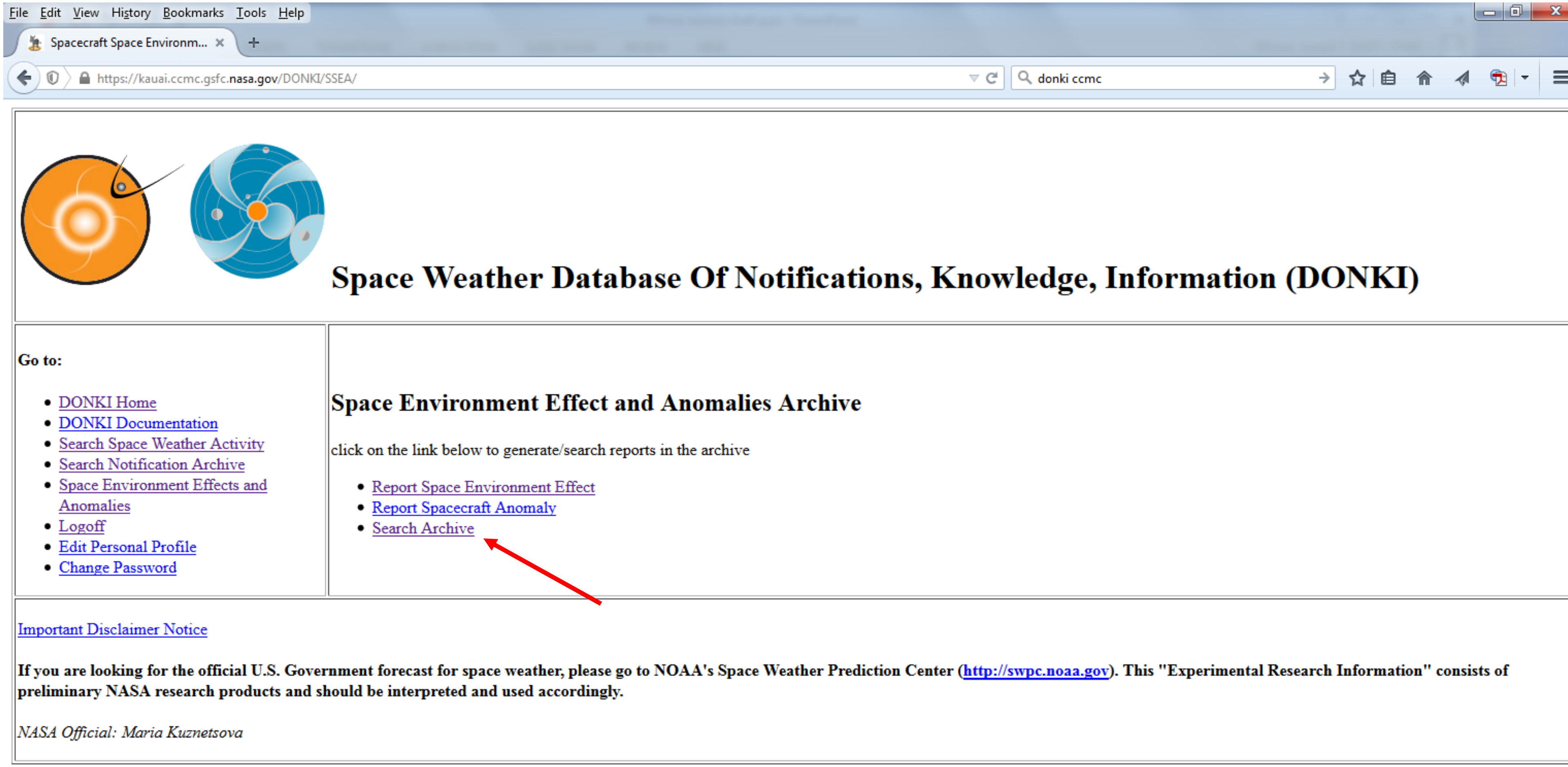
Important Disclaimer Notice

If you are looking for the official U.S. Government forecast for space weather, please go to NOAA's Space Weather Prediction Center (http://swpc.noaa.gov). This "Experimental Research Information" consists of preliminary NASA research products and should be interpreted and used accordingly.

NASA Official: Maria Kuznetsova

http://kauai.ccmc.gsfc.nasa.gov/DONKI/

Space Environment Effect and Anomalies Archive



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Search SSEA data

https://kauai.ccmc.gsfc.nasa.gov/DONKI/search/SSEA

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Activity ID	Project Name	System	Effect Time in UT	Orbit Type	Effect Type	Effect Description
2012-02-27T03:24:00-CHANDRA-RAD-001	CHANDRA	instrument	2012-02-27T03:24:00Z	Elliptical	radiation event	2012/058: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 27 Feb at 03:24 UTC to 27 Feb 20:23 UTC (16.9 hours) by a manual event due to ACE P3' (soft) particle signature.
2012-03-07T05:30:00-CHANDRA-RAD-001	CHANDRA	instrument	2012-03-07T05:30:00Z	Elliptical	radiation event	2012/067: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 7 Mar at 05:30 UTC to 13 Mar 05:14 UTC (122.2 hours) by an auto event due to HRC (hard) particle signature.
2012-03-09T12:00:00-ISS-CHRG-001	ISS	vehicle	2012-03-09T12:00:00Z	Inclined	spacecraft charging	2012/069: ISS auroral frame charging observed at high southern latitudes in period 12:00 UTC to 16:30 UTC. Maximum frame potentials ~6 to 14 V. Kp=5.7 to 6.7 at times of significant charging. Charging levels from ISS Floating Potential Measurement Unit.
2012-03-10T10:00:00-ISS-CHRG-001	ISS	vehicle	2012-03-10T10:00:00Z	Inclined	spacecraft charging	2012/070: Possible ISS auroral frame charging at high southern latitudes in period 10:00 UTC to 14:00 UTC. Maximum frame potentials ~1 to 2 V. Kp=2.0 to 2.7 at times of significant charging. Charging levels from ISS Floating Potential Measurement Unit. (Note: Additional verification required due to low Kp.)
2012-03-13T22:41:00-CHANDRA-RAD-001	CHANDRA	instrument	2012-03-13T22:41:00Z	Elliptical	radiation event	2012/073: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 13 Mar at 22:41 UTC to 14 Mar 13:57 UTC (14.8 hours) by an auto event due to HRC (hard) particle signature.
2012-05-17T02:18:00-CHANDRA-RAD-001	CHANDRA	instrument	2012-05-17T02:18:00Z	Elliptical	radiation event	2012/138: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 17 May at 02:18 UTC to 18 May 04:52 UTC (26.1 hours) by an auto event due to E1300 (hard) particle signature.
2012-07-12T19:59:00-CHANDRA-RAD-001	CHANDRA	instrument	2012-07-12T19:59:00Z	Elliptical	radiation event	2012/194: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 12 Jul at 19:59 UTC to 14 Jul 00:09 UTC (17.1 hours) by an auto event due to E1300 (hard) particle signature.
2012-07-14T21:08:00-CHANDRA-RAD-001	CHANDRA	instrument	2012-07-14T21:08:00Z	Elliptical	radiation event	2012/196: Chandra X-Ray Observatory (CXO) Advanced CCD Imaging Spectrometer (ACIS) instrument radiation intervention. Science observations interrupted 14 Jul at 21:08 UTC to 16 Jul 05:16 UTC (22.3

Space Environment Effect Report

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Space Environment Effect Report
Activity ID: 2012-03-09T12:00:00-ISS-CHRG-001
Project/Spacecraft Name: International Space Station
System: vehicle
Orbit Type: Inclined
Effect Time (UTC): 2012-03-09T12:00:00Z
Effect Time (MLT):
Effect Type: spacecraft charging
Location Info: LON=None Entered LAT=None Entered ALT=None Entered (undefined)
Effect Duration: None Entered
Effect Magnitude: undefined
Allow Public Access: false
Description:

```
2012/069: ISS auroral frame charging observed at high southern latitudes in period 12:00 UTC to 16:30 UTC.
Maximum frame potentials ~6 to 14 V.
Kp=5.7 to 6.7 at times of significant charging.
Charging levels from ISS Floating Potential Measurement Unit.
```

Image file:FPMU summary data

Submitted on 2014-09-30T19:42Z by Joseph Minow

Edit This SE Effect Report

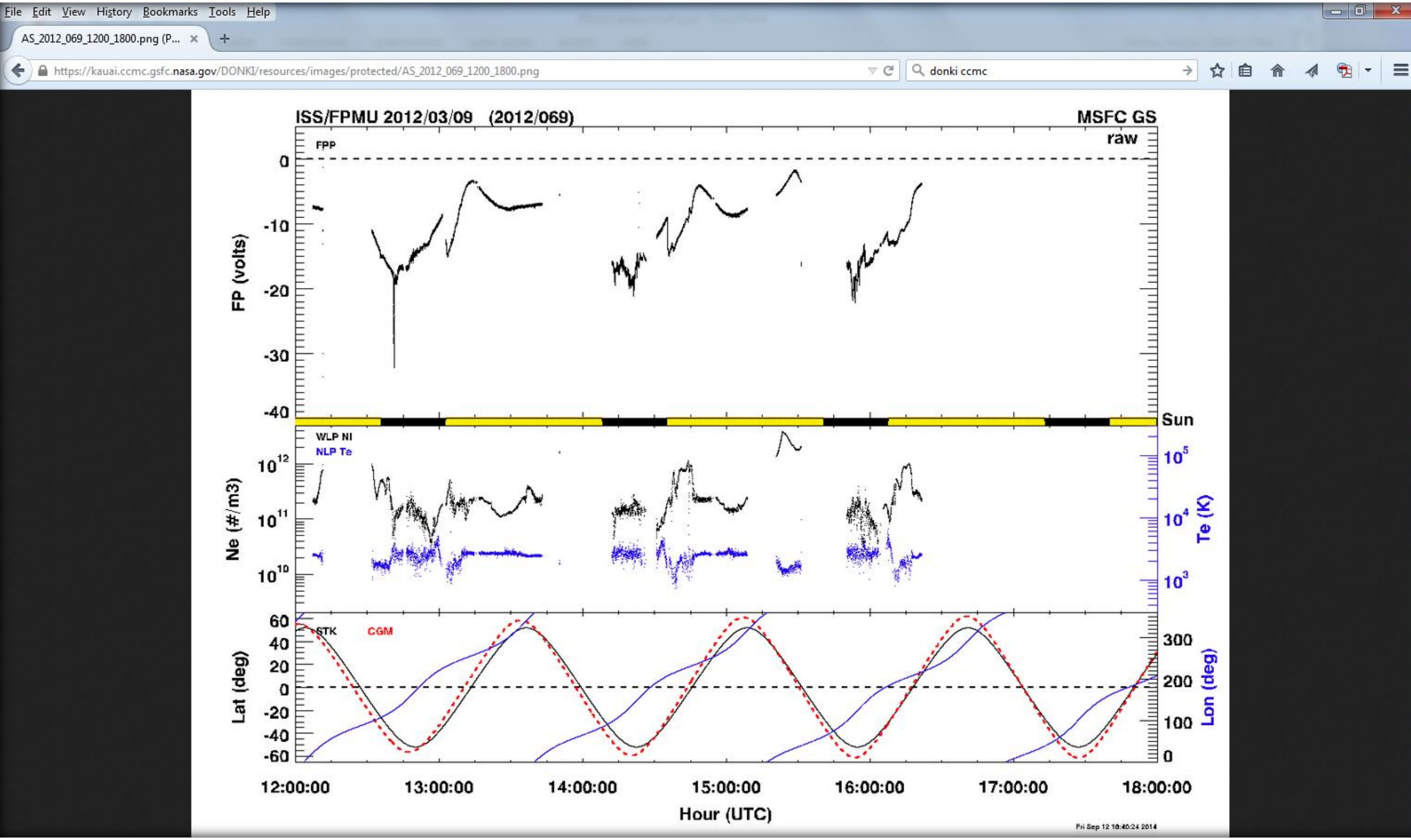
Add Related Space Weather Activity

All directly linked activities:

2012-03-09T03:00:00-GST-001 NOAA Kp: 7 (2012-03-09T06:00Z) NOAA Kp: 6 (2012-03-09T12:00Z)	DELETE

Post a Comment:

Space Environment Effect Report




Questions?
iss030e131395.jpg
GMT: : 2012:03:07 16:18:15